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Designing the Desirable Smart Home: A Study of Household Experiences and Energy Consumption Impacts

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ABSTRACT
Research has shown that desirable designs shape the use and experiences people have when interacting with technology. Nevertheless, how desirability influences energy consumption is often overlooked, particularly in HCI studies evaluating the sustainability benefits of smart home technology. In this paper, we present a qualitative study with 23 Australian households who reflect on their experiences of living with smart home devices. Drawing on Nelson and Stolterman's concept of *desiderata* we develop a typology of householders' desires for the smart home and their energy implications. We structure these desires as three smart home personas: the helper, optimiser and hedonist, which align with desiderata's three approaches to desire (reason, ethics and aesthetics). We use these insights to discuss how desirability can be used within HCI for steering design of the smart home towards sustainability.

Author Keywords
Sustainability; desirability; smart homes; energy consumption; domestic; desiderata.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

INTRODUCTION
Despite a tradition within HCI to focus design and evaluation efforts on utilitarian and functional benefits [31], envisioning what is desirable when designing interactions has long been recognised as an important aspect of design [42]. Towards this end, HCI research has looked for ways to embed pleasurable [30,31] and cool [27,49] experiences into interactions, acknowledging that, although interaction designs themselves can be desirable, it is the meaningful and desirable experiences they create and shape that give value to people [25]. The design challenge of creating meaningful and desirable experiences within the smart home has also been addressed within the HCI community [28,70]. Despite these efforts, how householders create and shape desirable experiences within the smart home is often overlooked in sustainable HCI studies that evaluate the use and effects of smart home technologies. Instead, sustainable HCI efforts tend to look for ways to design interactions that engage households in various issues of sustainability such as saving or shifting energy usage [34,44,60]. In this line of work, automation has been explored as the means to make sustainable changes more effortless or convenient [2,29,72], while eco-feedback has been used to persuade people to engage in sustainable change [21,34,62]. This research reflects a common framing within sustainable HCI; change is driven by a problem solving approach [42] that explores designs based on what is technical achievable and justified by the ethical (and desirable) premise that we are also solving sustainable problems.

However, as smart devices are moving into our homes, so too is a myriad of other desirable uses that extend beyond sustainability problem-solving goals. Devices are used in a variety of energy-consuming practices like heating, lighting, entertainment, and cleaning, which promote desires of comfort, convenience and entertainment [23], encompassed in the broader smart home aesthetic vision of 'pleasance' [64]. While much effort has gone into considering how these devices can be designed to make people's life more efficient and effortless [66], little attention has been given to what makes the smart home desirable and what energy consumption is tied up in that.

In this paper, we present a qualitative study exploring how desirability embedded in smart home designs shapes and enhances everyday experiences and energy consumption. More specifically, we seek to improve our understanding of desires that do not directly involve sustainability, but have sustainability implications. To do so, we draw on research (interviews, photography and home tours) with 23 households who incorporated various smart home devices into their daily lives. We analyse these data using Nelson and Stolterman's concept of *desiderata* [42] to develop a typology of householders' desires for the smart home as a helper, optimiser and hedonist. Our findings present insights into the desires embedded into the design of smart home devices and reflected in household practices, while also considering their energy implications. We use these insights to discuss the future role of HCI in designing the desirable sustainable smart home.

RELATED WORK

The smart home has long been envisioned as a home comprised of pervasive, intelligent, and interconnected technology [24] that predicts and responds to inhabitants' needs for comfort, convenience, entertainment, and security [3]. The design challenges embedded in this vision have caught the attention of HCI and ubicomp practitioners and researchers [11,19]. Three HCI visions have informed this work: calm computing [66], engaging experiences [53], and the sustainable smart home [2,52].

Weiser and Brown' vision of *calm computing* promotes designs that aim to hide smart technology as much as possible. Most work in this area has focused on the design and evaluation of the utility and usefulness of smart technology that enters the domestic space [8,11,19]. On the other hand, Rogers' vision of *engaging experiences* promotes designs that empower people to extend and engage in their daily activities and pursuits [53]. Work in this area draws attention to design challenges of designing interactions for pervasive technology that is embodied within the messiness of everyday life [4]. Towards this end, Klapperich et al. [35] explore how to design more meaningful interactions with automatic coffee grinders that reconcile automation and experience of everyday practices, while Mennicken et al. [40] acknowledge that the smart home vision continuously evolves as peoples' expectations of the smart home keep changing.

The vision of *the sustainable smart home* has also engaged HCI scholars over the last decade [2,5,16,52]. In this endeavour, HCI research has explored designs of smart home technology that aim to support households to sustainably use energy, either by reducing or shifting energy usage [45]. A number of studies have investigated how smart automatic agents can assist households to effortlessly manage heat consumption [1,29,36,56,73]. Examples are Alan et al.'s three smart thermostats [1], Scott's et al.'s Preheat system [56], and Yang et al.'s [71,72] extensive user study of the NEST Thermostat (a commercial smart thermostat that promotes energy savings by intelligently deducing households' comfort needs).

Other sustainable HCI research has explored the role of smart devices in assisting households to sustainably manage their electric car's consumption [10], or other domestic practices, e.g. washing clothes [7,15]. While these studies have shown promise for smart agents to help households obtain energy savings, they also draw attention to the challenges of designing devices embedded in everyday life [15]. Importantly, what unites this work is an assumption that the sustainable smart home should uphold households' lifestyle expectations of comfort and convenience [29,72].

However, as smart home technology is finding its way into homes, so too are many challenges [68]. One is to address a potential mismatch between households' and the smart home industry's expectations of how such technology should be used. As Wilson et. al recent study [69] shows, prospective smart home users identify one of the desired benefits of smart home technology as enhanced control of energy. However, a recent analysis of industry visions [64] demonstrates how the smart home technology industry also embeds desires into these devices that promote energy-intensive comfort and convenience.

Desiderata

Desires have been acknowledged as contributing to human intent [42] and shaping expectations for how we want to live [59]. Therefore designers have long attempted to inscribe desires into designs in an effort to shape experiences to become more pleasurable [31], cool [49], and meaningful [26]. However, research also shows that people appropriate and shape their use of such designs in ways that are unforeseeable [17,26].

So how can we understand people's everyday engagements with design? One way is to look at Nelson and Stolterman's concept of *desiderata* [41,42], which loosely translates to 'desired things'. Nelson and Stolterman propose that incentives to engage with a desirable design are influenced by intrinsic motivations shaped by people's desires [42].

Viewing desiderata as a concept to understand desires embedded in design includes three strategies roughly condensed to *reason*, *ethics*, and *aesthetics* [42]. Reason is related to what a design object *is* or *needs to be*, or its purpose and the reason why it exists. Ethics corresponds to what a design object *ought to be* based on ethical and moral codes, while what we *want* a design object to be is expressed in aesthetic values of experiences [41,42]. Together these three strategies capture a more 'inclusive whole' of desires in design – desiderata – forming the voice of design [42]. However, there is never only one of these approaches present in a design, as a design consists of *"different proportions and balances among these three approaches"* [41]. For example, desires embedded in a smart thermostat could be viewed as the following: we might desire to control the temperature in our house (reason), so that we don't waste energy (ethics), while also ensuring a desirable comfortable temperature throughout the home (aesthetics). Thus, these desires together (desiderata) make the smart thermostat a desirable thing.

We combine the concept of desiderata with Shove and colleague's [57,58,59] interpretation of how desires shape expectations and in turn become embedded in (or rejected from) everyday practices. Shove [57] argues that desires have played (and continue to play) a critical role in shaping normality, by steering the kinds of 'comfort, cleanliness and convenience' (the '3Cs') people aspire towards and expect. Following Shove et al. [58], we can also understand such desires as social – arising out of and shaping social practices as part of the meanings, ideas and moods that orient everyday activity towards shared expectations. This means that 'desired things' can shape, but not determine, how people use a design or what they expect it to do. Importantly, Shove [57] argues that these have significant energy consumption effects; the 3Cs, for example, constitute ‘the environmental hot spots of consumption’ making them ripe for sustainable HCI scholarship.

Indeed, this approach has become of increasing interest to the field of sustainable HCI in recent years [20,39,43], as scholars seek new ways of understanding how to embed sustainability within everyday practices, and make it desirable [38,46]. We extend this scholarship here by analysing how desiderata shapes householders’ desires and expectations for the smart home, and contributes to or undermines sustainability outcomes.

METHODS

The research reported in this paper is part of an ongoing 3-year qualitative study of 23 Australian households living in smart homes or using smart home technologies led by author 2. The study involved semi-structured interviews and home tours supplemented by photographs and observations. The research was conducted with approval from RMIT University’s Human Research Ethics Committee.

Participants

35 people from 23 individual households participated in the study (Table1). Most participants were 25 years or older but two households included children in the interview. Most households who disclosed their incomes were high income earners. The households were recruited through technology forums and events, a project website, social media, radio and print articles, advertisements, referrals from smart home industry professionals, and professional and personal networks. Each household was offered an AU$50 voucher.

To be eligible for this study, each household had to self-identify as using at least one smart home device fitting Aldrich’s definition of a smart home [3]. This open recruitment criteria reflects current research which indicates that the technology, visions and expectations for smart homes are a work-in-progress [40,68]. The number and type of smart devices in participant households was diverse (see Table 1) ranging from one smart device (e.g. robotic vacuum cleaner) through to fully integrated smart homes with a range of connected devices and appliances providing lighting, entertainment, security, comfort, energy management and garden irrigation. Ten households also had solar panels for hot water or electricity generation.

Data collection and analysis

Site visits lasted between 1-2.5 hours. Broadly, question topics included: participants’ understandings of the smart home and its associated technologies; why they have them and what a smart home means to them; experiences of living with smart home technologies; energy consumption; and aspirations and predictions for future smart home technologies. Most (21) interviews included an informal conversational technology tour [6] during which participants demonstrated how they use their devices or smart home. Researchers asked clarifying questions and took photos if permission was granted.

Interviews and home tours were audio recorded and professionally transcribed resulting in a single transcript. As we set to investigate how householders’ desires for smart home devices inform their practices, the units of analysis were desires and expectations. The transcripts were coded in two stages by author 1 (under the direction of author 2). In the first stage, we identified broad themes via inductive

#	Anonymised Participant(s) (gender)	Adults (children)	Occupation	Age of participant(s)	Smart Home Devices
H1	Kahlil (M)	2	Software developer	35-44	Robot vacuum cleaner,TV
H2	Lindy (F), Johnno (M)	2 (2)	Education support, electrician	35-54	Alarm system, garden irrigation, windows, fans, touch screen panels
H3	Tony (M)	1	Academic	45-54	Lights, entertainment system, automated security camera, windows
H4	Jerry (M)	2	Financial Manager	55-64	C-bus, lights, TV, air conditioning, music, security cameras, garden irrigation
H5	Rachel (F)	2	Not in paid work	35-44	Automatic locks, lights, switches, music, TV, intercom
H6	Bill (M) Kristi (F)	2 (1)	Management Feng Shui and teaching	45-54	Robot vacuum cleaner, security system, lighting, blinds, pool, entertainment, Amazon Echo ‘Alexa’, touch screens panels, security cameras, fans, home cinema
H7	Gavin (M), Kate (F), Daughter 1, Daughter 2	2 (2)	School teacher, homemaker, Student, student	45-54 16-18	Control 4 system, lights, security cameras, windows, blinds, sound system, skylights.
H8	Scott (M), Lauren (F)	2 (3)	Engineer, radiographer	45-54	KNX system, Amazon Echo ‘Alexa’, air conditioning, lights, weather station.
H9	Darren (M)	2 (1)	Arcade game businessman	45-54	KNX system, lights, curtains, security cameras, doors, temperature, music, fire place
H10	Trent (M)	2 (1)	Builder (own business)	45-54	C-bus, entertainment, heating, air condition, lights, security system, touch screen panel
H11	Ted (M), Jess (F)	2	Software developer, research student	35-44	Robot vacuum cleaner, smart meter home display, fitbit scale
H12	David (M)	2 (2)	Project manager, kindergarten teacher	45-54	C-bus, lights, automatic sprinklers, security system, rain sensor, blinds, water features, audio system, security cameras, touch screen panels, home cinema
H13	Taryn (F), Matt (M) Son1, Son2	2 (2)	Full time student, researcher, Student, student	45-54 10-13	Robot vacuum cleaner, music system
H14	Larry (M)	2 (2)	Real estate business	55-64	Lights, doors, air conditioning, security system, sprinkler system
H15	Romy (F)	2 (1)	Physiotherapist	25-34	Blinds, light, air conditioning, music system, doors, gate, security cameras, sensors, garden irrigation, intercom
H16	Demi (F)	2 (2)	Teacher	25-34	C-Bus, music, irrigation, lights, touch screen panels, sensors, doors, security camera, air conditioning, roller shutters, blinds,
H17	Valerie (F)	2 (2)	PhD student	45-54	Robot vacuum cleaner
H18	Adam (M)	2	IT services	35-44	Lights, security cameras, music, smart meter home display
H19	Morris (M)	1	IT developer	35-44	Lights, gates, blinds, Google Home, Amazon Echo Dots, Robot vacuum cleaner, TV, air conditioning
H20	Kurt (M), Graham (M)	2	Economist, teacher	25-34	Lights, music, fitbit scales
H21	Cara (F)	1 (2)	Homemaker	45-54	Lights, music, blinds, air conditioning, touch screen panels, doors
H22	Pablo (M), Noni (F)	2 (2)	Ethical investment research, public service	35-44	Heating and air-conditioning, smart meter home display, robot vacuum cleaner
H23	Gabriel (M)	2 (3)	IT architect	35-44	Z-wave, Google Home, pool, lights, sensors, gates, smart meter home display

Table 1: Summary of participant households.

coding [51,54]. In the second stage, we conducted structured thematic coding informed by Nelson and Stolterman's framework desiderata [41,42], and Shove and colleagues' [57,58,59] understanding of how desires shape household expectations and everyday practices [37,38,58], focusing on those likely leading to 'hot spots' of energy consumption [57]. We used this analysis to develop a typology of smart home desires, which is a common analytical device for organising qualitative data [55]. Throughout this paper, participating households are referred to by pseudonyms and household number (see Table 1). Quotes are verbatim.

FINDINGS

Our research is informed by other studies indicating a potential mismatch between household's [69] and the smart home industry's [64] expectations for the smart home. Despite numerous HCI studies providing insights into how to design both desirable and sustainable interaction designs, there has not been any HCI research synthesizing household experiences to explore how desires shape energy consumption in the smart home. Towards this end we present findings from our qualitative data analysis.

Analysed through the lens of desiderata, we identified a typology [55] of 10 desired characteristics of the smart home informed by the households participating in our study. While these key characteristics can both conflict and overlap, we structure them into three 'smart home personas' that align with desiderata's three approaches (reason, ethics and aesthetics): *the helper*, *the optimiser* and *the hedonist.*

As these desires are informed by reflections of the participants' experiences of living with smart home devices and how they expect these desires to be realised, the three personas represent householders' desires for smart home devices or the smart home in general (see Figure 1). *The helper* captures desires related to the smart home's function and its capability to act in a helpful manner. *The optimiser* captures characteristics related to desired outcomes for the smart home. *The hedonist* captures a pleasure-seeker pursuing desired aesthetic experiences within the smart home, suiting a modern lifestyle. Figure 1 presents our typology of smart home personas and characteristics.

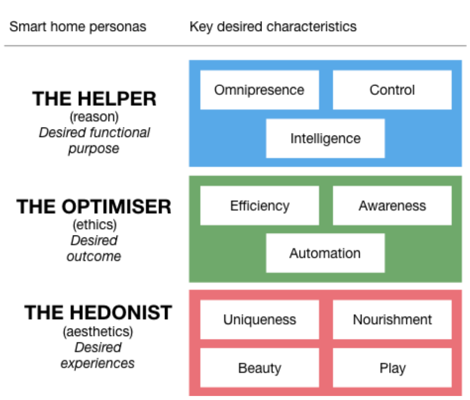

Figure 1: Households' desires for the smart home.

In the remainder of this section we present our analysis of these three desirable smart home personas and their related characteristics. We focus on the characteristics that indirectly and directly have implications for energy consumption.

The Helper

The helper captures households' desires regarding the purpose of the smart home expressed through functionality. What makes the helper desirable is its ability to assist households to control appliance and housing features and functionality, thereby saving time and making home life more convenient. The helper strategy is evidenced by the smart home's subtle way of combining intelligent features of different devices, accessible when needed, resulting in a controllable omnipresence throughout the house, an aspect well summarised by Gabriel:

> "Where everything is connected to everything; devices can control one another and can do so both reliably … and intelligently. Self-learning as well, so you can say if you've just bought a new oven, okay, I'll add that to my abilities of Google Home over there." Gabriel (H23)

However, attaining these desired smart features also means that new electricity-consuming devices are brought into the smart home (e.g. Google Home, Philips Hue Bridge, and robotic vacuum cleaners). Interestingly, based on participating households' experiences, most of these electrical devices do not replace others but are added to the household's fleet of devices, impacting overall energy consumption. More specifically, our analysis found that the helper's desired characteristics created new demands for electricity. We now turn our attention to these.

Omnipresence

One desired characteristic highlighted by most households is the smart home's 'always-on' ability to provide smart features when needed. This characteristic is related to Weiser and Brown concept of calm computing [66] where interactions are designed to only take centre stage when control is desired. However, providing this kind of omnipresent control also means devices are consuming small amounts of energy all the time in 'standby' mode.

Most devices present in the households embodied this omnipresent characteristic. Some were remotely controlled devices (e.g. smart fans, blinds or lights) always ready to execute commands on behalf of the household. Other devices provided pervasive control through an assembled interface. Examples included Google Home and Amazon (Echo) Alexa, devices that offer omnipresent voice control to connected smart devices and the internet. In some of these homes Alexa helped to control other smart home devices: *"like turn lights on and off, turn the fountain on and off, raise and lower the blinds"* Bill (H6). Other times 'she' helped the householder more directly:

> "Alexa has lifted the whole thing … you can ask her the weather and she does calculations. So she puts on a timer. Yeah so it's kind of like having a helper." Kristi (H6)

However, to serve household's needs when called upon, devices like Alexa and Google Home are always 'listening in' on household conversations. This uses almost the same amount of electricity compared to when these devices are actively helping householders [18].

Control

Another key characteristic of the helper persona involves providing control to the smart house. This involves allowing householders to monitor and access their home, including its physical boundaries and the property's perimeter, through e.g. lighting and security devices.

Based on householders' experiences this desired characteristic was associated with many smart home devices (e.g. smart lighting, security doors and cameras, and air conditioners). For example, security doors allowed some households to control and monitor who had access to the house when they were away, as Darren explains (H9): *"I can let them in my front door, and I can be in Glasgow"*. Most households saw this aspect of the helper as a time saving feature in a busy modern life: *"well it does save time, yeah. I don't have to go there"* Larry (H14). This also highlights a desired aspect of the helper to make home life more convenient, as explained by Romy:

> "Like when I was breast feeding … [my child], if I had to turn the air con on or off or lighting or dim the lighting or whatever, I didn't have to stop doing that to be able to go – you know, like go switch a light on or off." Romy (H15)

To be able to provide this kind of access, new energy-consuming devices are often needed. For example, the Phillips Hue Bridge is an additional device, not normally present in households with non-smart lights, which is constantly running in order to access smart bulbs from a smartphone. In about half of the participating homes, this desired accessibility was also facilitated by a centralised 'hub', allowing smart home devices to communicate with each other and the Internet.

> "So that's a switch, so that's for all the network points throughout the house, so the speakers, TV, the phones, all that is through there. That's the security camera […] That's the router, and that's the Hue, so actually quite simple, as you say, as these things go." Adam (H18)

However, not only does such a 'hub' need a constant supply of electricity to power the 'brain' of the helpful smart home but it also creates new energy demands like cooling down the server racks (see Figure 2) or entire server rooms: *"that's the air conditioner for our control room. So that's to keep all the electronics cool"* Bill (H6). Furthermore, for households wanting to maintain control over the smart home through this centralised hub, other energy-consuming devices like Alexa and Google Home were used. Some houses also used situated powered smart screen panels (see Figure 3). These displays were often placed throughout the house providing access to the smart home when desired:

> "Again, here is a touch screen. So, on the touch screen, you could have things like your favourite pictures come up. … This is a page, so it basically has the main, the front, the pool, the theatre room downstairs, outside, and then it has the tools where it shows you how to program." Trent (H10)

Figure 2: A smart home 'hub' accompanied with a cooling system (H18).

Figure 3: Smart screens panels providing access to connected devices (H6).

In other words, instead of reducing standby power consumption and the human energy required to do so, the smart home employs a range of new energy-consuming devices with the intent of saving time or household labour.

Intelligence

Most participating households also desired some level of intelligence from the helper. More specifically, they wanted the smart home to anticipate and react to new changes and conditions in the home environment. This level of desired intelligence was found in most households, where smart lights would go on/off based on movement, smart locks opened doors based on geo-location of householders, and windows opened or closed based on local conditions like weather and time.

> "I programmed the house to do certain things, like my front door, the porch light turns on at sunset and turns off at 11:30 […] It's geo-fenced, so when I'm driving home and it's after dark, that light turns on. So that's the smart sort of stuff. The blinds I'll program to open at sunrise and sunset." Morris (H19)

Households made use of the smart home's intelligence by using 'set and forget' or automated features to free up time for more enjoyable activities: *"So, we can spend more time being creative instead of having to do, yeah, manual work"* Kahlil (H1). To enable this desired reactive, intelligent mode, sensors were used to detect proximity of home occupants to unlock or light up areas of the home:

> "LED lighting underneath the cupboards as well, and that comes on with the sensor as you see. I just walked in and it comes on automatically." Darren (H9)

Intelligence was also delivered by helpful communication offered by many smart home devices that are designed to provide visual cues about the status of a device – most often accomplished via LED lighting. For example, the Phillips Hue Bridge is designed with a blue LED light that is constantly lit to communicate that it is on. Other devices like sensors told householders that movement had been detected via LED lighting. Kate and Gavin identified the light "pollution" (and energy demand) tied up in this interactive communication provided by their sensors:

"I'd like to coin the phrase LED pollution. And that is that, when you turn the lights out and devices have LEDs to just even show standby it's such a strong light, it's such a bright light that, you really never get that compete darkness anymore because everything has, LED whether it's just a clock, whether it's a, standby button, whether it's – everything has to tell you it's state via LED." Gavin (H7)

What these findings show is that different desired functionality embodied in the helper also implicit have implications on electricity consumption in the smart home.

The Optimiser

The optimiser is a second smart home persona. The optimiser captures desires related to how the smart ought to be used related to a desirable outcome. It is characterised by its desired ability to use energy more efficiently and with less effort while maintaining expectations of comfort and convenience. It does so by providing awareness about consumption to household members and anticipating how to use consumption more efficiently through automation.

The optimiser contrasts with the helper and hedonist by highlighting a paradox in household desires for the smart home: namely, that the smart home is a house that uses energy efficiently, but also helps (the helper) householders to create experiences (the hedonist) that reflect a modern lifestyle, regardless of their additional energy needs. Some of the participating households noted this paradox:

"I certainly love that you can use some of this stuff to save energy, but also, you have to think about all of the embodied energy if you're getting new devices every couple of years – that's energy as well." Rachel (H5)

In the following we describe the desired characterises of the optimiser and this paradox in more detail.

Efficiency

The desire to bring smart home devices into the home was often related the optimiser's desired characteristic of using energy more efficiently and being more economical with energy consumption. The following couple explicitly expressed this desired characteristic:

"To me a smart home would be using, would be really be very low on electricity use." Kristi "That would be an economical home." Bill (H6)

The desired characteristic of the optimiser to use energy efficiently meant that living in the smart home was also tied together with living sustainably for some households: *"So it's basically being more sustainable, that's, well that's what I'd consider a smart home, actually"* Pablo (H22). Interestingly though, most devices found in participant households do not explicitly promote sustainable energy usage in their product marketing even though householders' often used this reason as a justification for bringing these devices into their homes [65]. David, for example, explained that energy efficiency had been an important consideration when he decided to bring a smart heating system into his family's home. However, he understood that energy efficiency was the responsibility of designers:

"I think because there's a consumer desire to minimise energy usage then the technology will support that, and yes, … [product designers will] help improve or reduce energy consumption." David (H12)

This finding demonstrates how some householders view energy consumption as a 'feature' that is the responsibility of designers, rather than seeing it as an outcome of smart home devices becoming integrated into everyday practices such as heating.

Awareness

A second desired characteristic of the optimiser was to educate household members about sustainable energy usage by prompting them to use energy more efficiently. This is connected to some householders' desires to understand their own energy usage and give them control to do something about it, as explained by Trent:

"If I've forgotten to - or he's [my son's] forgotten to turn the lights off in his studio, and it shows up on the screen. So I can do it from my phone or do it from upstairs, turn them off, you know." Trent (H10)

In most of the participating homes, raising awareness was seen as a desired means towards more efficient energy use. Some householders thought awareness was a matter of getting to understand the smart home better, like Kate (H7): *"for me I think once we get to know the system and how to work it, I'm hoping that it will reduce [consumption]"*. Others saw real-time and historic consumption feedback visualised through their smart home system as a way to manage their energy usage. This kind of feedback for some raised awareness about spikes in energy use which Ted (H11) described as getting *"a kick out of that, just being able to measure how much energy we were using"*.

However, whether this characteristic of the optimiser is really desirable can be questioned. Adam (H18) had at first found this kind of feedback interesting but it ended up being an element which he *"set … up but haven't paid a lot of attention to"*. This shows that although this kind of feedback is initially desired, it also relies on ongoing (undesirable) householder engagement.

Automation

Despite a desire to become aware and maintain control of energy usage, the optimiser is also characterised by the smart home's desired ability to anticipate when to act sustainably through automation.

"Our house does the same thing when you go out and we turn the alarm on it turns any lights that you've left on in the house, it would turn them off so that you didn't leave something on and waste energy." David (H12)

This aspect of the optimiser assumes that householders are busy and forgetful and thus the optimal way to obtain energy efficient benefits is through automation:

“Some people are pretty lazy… So automation systems can be useful for people who, you can set timers. You can have a control. You can switch lights on from, on and off from a control and that will reduce your consumption.” Kahlil (H1)

However, adding this kind of automation to smart home also had energy implications. For example, while Bill was aware that smart devices might not lead to more energy efficient use, *“because we’ve got lots of gadgets it’s not as efficient as I’d like it to be”*, he believed energy benefits could be obtained by better planning how to automatically turn *“more appliances and devices off”*. This is interesting because although most households saw smartness as a means to make the home more efficient, most households reported using more electricity than they had previously.

While automation in these circumstances was a desired means to *not* waste energy, our analysis also shows that automation can undermine potential energy benefits. Johnno mentioned the energy paradox in setting up a smart home to do work on behalf of the household:

“If you let something else do the work for you, therein lies the energy cost.” Johnno (H2)

For example, in some homes a robotic vacuum cleaner was used, but because this task was efficiently carried out by a smart device they vacuumed more frequently to pursue higher cleanliness expectations as reflected by Taryn:

“There’s just the sense of the house feeling cleaner and that’s a nice feeling. And it’s a very personal thing to me… It has crossed my mind that maybe we’re using more energy because it cleans more often.” Taryn (H13)

Others continued to vacuum manually (in addition to robotic cleaning) because their robotic vacuum cleaner did not live up to their cleanliness expectations: *“on Saturday we’ll have a big clean so we’ll get the proper vacuum cleaner”* Valerie (H17).

This aspect of the smart home highlights one of the challenges of designing the sustainable smart home. If the optimiser is going to be successful in achieving desired sustainable energy outcomes, conflicting expectations of desired characteristics of the smart home, needs to be addressed.

The Hedonist

The hedonist conceptualises household desires of *wanting* to experience the smart home as an aspirational modern lifestyle, as encapsulated in the industry vision for ‘pleasance’ [64]. The hedonist is characterised by its capacity to create a desirable and beautiful living space that also makes the smart home more playful and cool to be in. Moreover, what makes the hedonist desirable is its ability to adapt to a household’s unique lifestyle needs by creating *aesthetic* experiences that are nourishing, personal, and pleasurable, as Kristi explains:

“So to me in Feng Shui terms a smart home would be one that reflected your soul. It would reflect exactly what you love. So it wouldn’t be what’s in a magazine - it would be what nourishes you and what symbolises you.” Kristi (H6)

Some of the characteristics of the hedonist are afforded by the features and functionality of the helper. Interestingly though, the hedonist had the biggest impact on how smart home devices were used and experienced in households. Most had put considerable effort into designing their homes with smart devices to improve their quality of experiences both now and into the future:

“The home needs to be sort of designed that it will meet our needs throughout life, and that security and safety and comfort and all of those things are.” Gavin (H7)

However, creating and enhancing aesthetic experiences also have an energy impact as we identify in the hedonist’s characteristics below.

Uniqueness

A desired characteristic of the hedonist is how the smart home is able to create experiences within the smart home that are highly personalised. For most participants, this was about the smart home’s ability to fulfil the unique and personal needs to suit each household’s lifestyle:

“The house that works with you, so it's not an independent. It'll have to be a part of your life so it knows where you are. It responds, it's in keeping with your lifestyle.” Kahlil (H1)

From our analysis, it is clear that most households in our study had gone to great lengths to purposefully integrate smart home devices into the design of unique, intimate, and personal spaces in their homes. David, for example, had designed a personal music experience where:

“You can have different music playing in different zones, or at the touch of a button you can link them altogether and just have the same music throughout the house.” David (H12)

David created this experience by placing energy-consuming speakers in most rooms of the house and even ensured that music could be reached to the outside area of the house. Other households used smart lighting to create unique atmospheres suiting the mood of the household. For example, Tony (H3) used his smart lighting system to create unique intimate atmosphere suiting the particular space and the moment in time: *“I will change the lighting if I think it will make a better space”* (see Figure 4).

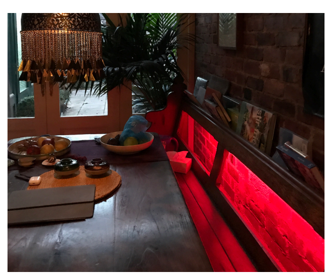

Figure 4: Creating a cosy atmosphere at the dining table with LED strips (H3).

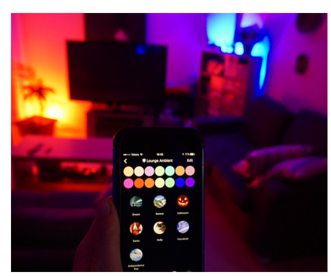

Figure 5: Smart lighting used to a unique atmosphere in the living room (H22).

Mood and automated lighting in particular were quickly integrated into existing practices (e.g. cleaning, dining, bathing, sleeping, and entertainment) to create a more intimate and cosy atmosphere:

> "The atrium feel, you know … just when we have dinner parties, … at 10 o'clock at night the lights dim by themselves, I don't have to get up and dim the lights, so they reduce down to 35 per cent." Trent (H10)

This meant that devices such as LED strips and other energy consuming devices were used more extensively in everyday practices as they found their way into households' TV lounges (see Figure 5) and dining rooms.

Nourishment

Another desired characteristic of the hedonist is its ability to nourish householders by making everyday life more convenient, comfortable and secure. The desire to feel safer was evident in many of the households we interviewed. Some used security video cameras to record movement in and around the house. Some households with smart lighting would also use programmed lighting when away:

> "When you're [on] holidays, you know, we have the simplicity of making sure the lights are turned [on] and turned off at certain times so it looks like someone's home." Trent (H10)

In other homes, smart blinds and windows were used to ensure that it would not get too warm inside the home during sunny summer days. In houses with smart thermostats, some householders would ensure a comfortable temperature when the house was occupied. Similarly, some households extended energy usage by turning the air conditioners and heaters on hours before returning home to ensure a comfortable house:

> "So it means that I can turn the air conditioning on half an hour before I arrive home and have a cool house to come home to, which is probably the most desired outcome of this whole system that I had." Scott (H8)

Bill and Kristi also pursued the hedonist's smartness to ensure a comfortable temperature in the spa before returning home: *"I'll turn the spa on and start it heating before I get home"* Bill (H6). Several households also used smart lights in new ways, such as to help them get to sleep. In Demi's household for example, they had a "kids bed button" that dimmed lights in designated places when the children were put to bed. They used a smart light to ensure that there was some nourishing light in case the children woke up and needed to visit the bathroom during the night:

> "So the button basically dims the lights in my younger son's bedroom to be the lowest dimness, so that he's got, it's kind of like having a bed light in there, I guess. As well as the hallway and the bathroom." Demi (H16)

In Scott and Lauren's (H8) house they used a "goodnight button" to ensure that all lights were off when they went to bed but still left *"the stair lights on at 10%"*.

This desired aspect of the hedonist also highlights implications of energy usage and the role of light and other nourishing energy-consuming devices in the home. As a nourisher, devices need to be on more of the time and therefore can increase energy consumption. For example, the 'goodnight button' leaves householders with the peace of mind that everything will eventually be switched off, instead of progressively switching things off throughout the day as they are no longer being used.

Beauty

The hedonist is also characterised by a unique ability to create a living space that is aesthetically pleasing. This is extended to other parts of the property, like the garden or swimming pool area.

In particular, smart lights were used by participating households to create aesthetically pleasing spaces. Bill and Kristi (H6) explained this when asked why they had decided to use LED lights in a fountain in the garden: "*it should be a very nice aesthetic advancement"*. To create an aesthetically pleasing experience by the pool, the same household also used coloured LED lights: *"both during the day and at night even more so",* a clear example of how the hedonist dominated the possible desired sustainable outcomes of the optimiser.

This domination of the hedonist was also evident in most of the other households. Scott (H8), for example, had spent much time and effort designing the lighting so it would be energy efficient but also appropriate to activities that suited his household's age and lifestyle. Decorating areas of the home gave him a lot of pleasure: *"yes, you got basic coloured lights outside around the pool. Just around the pillars. Just entertaining"*. Both David (H12 - Figure 6) and Gabriel (H23) had programmed all the outside lights to be turn on 10 minutes after dusk and turned off around bedtime because *"I always think houses that are nicely lit at night look good.*" Gabriel (H23).

Figure 6: Smart lighting in a fountain and on the outside wall of the house (H12).

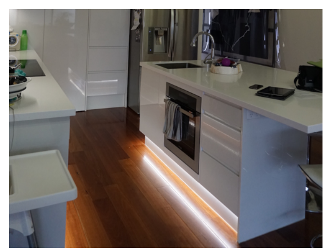

Figure 7: Decorative smart lights in the kitchen area (H9).

Trent (H10) used different kinds of lights like LED strips and halogen down lighting extensively as a decorative means to create these aesthetic pleasing spaces throughout:

> "Yeah. Decorative lights […] We've turned the light - and especially in summer. And you know, it just creates a nice backdrop [...] Feature lighting. And you know, it's nice at night, it just gives that ambience, you know?" Trent (H10)

However, this desire to create aesthetically pleasing and beautiful spaces also meant that more energy consuming devices are finding their way into places where they were not used before. For example, smart lighting was being used to decorate both interior (see Figure 7) and exterior spaces, like the garden, swimming pool, and pathways.

Playful

The final desired characteristic of the hedonist is its ability to make the smart house more playful, fun, and cool. This aspect was appreciated by many households who found it amusing spending time acquiring competences to set up and use the smart home to suit their needs:

> "I did it all myself. That's the fun for me [laughing]" Adam (H18)

It was not only adults that saw this value of the smart home. For example, the teenage daughters in H7 said that *"my friends just love our house yeah. They're just like, cool!"* Other householders also saw smart home devices as toys that were fun to 'muck around' with. This playfulness and the added bonus of feeling cool was sometimes used as a justification to bring new devices into the home:

> "I love it, it's totally cool! […] When the new Hue bridge comes around, I should be able to tell Siri what to do to it, […] it's like Star Trek in my living room! It's magic, and it's wondrous and fun." Rachel (H5)

This aspect of the hedonist demonstrates how play and coolness invite new smart 'desirable things' into the home.

DISCUSSION

Our study has demonstrated how householders' desires for the smart home shape expectations, everyday practices and associated energy consumption. However, we do note a potential limitation to this study. While we discuss the potential energy impacts of these findings in this paper, we did not collect any energy data from participating households, and therefore we rely on self-reporting and publicly available information on the efficiency and energy consumption of smart home devices. Nonetheless, our analysis shows that households' desires for smart home devices take different forms that sometimes overlap, and both complement and contradict each other. More importantly, our findings reveal that desires shape how the smart home is appropriated in ways that also can undermine the desire to save energy. The key energy implications of the three desired personas is summarised in Table 2.

We now discuss the implications of these findings for HCI researchers and practitioners.

Taking a holistic approach to desirable designs

A long tradition within HCI is to focus design efforts on understanding users and evaluating users' needs through design processes like user-centered design [48]. However, when design is driven by assessing users' needs and what is technical achievable (technology-driven design [33]), designers also frame designs as problems that need solving. While such efforts can be fruitful for understanding and evaluating use and driving technical inventions, they do not capture a holistic view of what makes a design a 'desirable thing' and how use and experiences are shaped through desires [26,42].

The helper	• New 'helpful' energy consuming devices • Devices ON 24 hours a day (standby power and remote energy consumption) • New energy demands like increased cooling and LED pollution
The optimiser	• Supports assisted living upholding desirable outcomes of comfort and convenience • Entrance of devices into home justified through energy efficiency benefits • Energy feedback focuses attention on small actions (e.g. turning lights off)
The hedonist	• Energy consumption is extended in time and place to create a nourishing effect • Energy consuming devices incorporated into entire property to create unique and beautiful living spaces • New devices enter the home because they are fun and cool

Table 2: Key energy implications of the smart home personas.

As we discussed earlier in this paper, this problem-solving approach to design also appears to dominate sustainable HCI efforts, which falls into two broad categories. The first encompasses interactive designs that engage people to reflect on their energy-consuming practices through design techniques like eco-feedback [14,21,34]. The second involves designing smart energy technologies that aim to make the transition towards more sustainable energy use as effortless and convenient as possible [29,56,71]. While these efforts show the potential for raising awareness and saving energy consumption, their long term implications on consumption is limited [12,62].

This is interesting because managing energy consumption, and saving energy has been recently identified as the main desired benefit of smart home technology by prospective smart home users [69] – a desire also identified in our analysis of householders' desires for the smart home. So why is it that this desire to use energy sustainably does not shape appropriation of these technologies alone? A possible answer can be found in the typology presented in this paper. The three smart home personas show how different desires shape how designs are adapted and incorporated into everyday practices and ratchet up expectations. Therefore, we believe an important call for HCI designers is to analyse, design, and critique our designs more holistically, through concepts such as desiderata, before making energy saving claims.

When visions and desires do not align

One step towards such efforts could be to consider aligning conflicting desires within the smart home and the visions designers embed into these technologies. As this and other recent studies [23] show, possible sustainable benefits within the smart home are undermined by other desires householders have of the smart home. Designers within the smart home technology industry seem partly to blame for this misalignment [63] as they tend to inscribe visions into the design of these technologies that are similar to the typology presented here, without much consideration of possible energy implications [64,65]. Inscribing visions into designs may have influenced this misalignment in the participating households' desires for using the smart home. However, they do not determine how people shape the use of such designs and incorporate them into everyday life as this is a more complicated and messy process [58]. Going back to our findings we see this complicated process played out in the smart homes of our participants. What the three smart home personas show is that use and experiences are shaped by householders' different desires that may play off against each other, either by justifying or undermining each other. So, where does the HCI researcher's role lie in re-aligning desirability and sustainability?

Designing the desirable smart home as low consuming

A possible approach for HCI researchers is to explore different ends towards desiderata. Inspirations in this direction could explore different desirable expectations of what meaningful low energy-consuming experiences are within the smart home.

One research opportunity could be to challenge the enhanced expectations of comfort, convenience, and cleanliness that also lies embedded in the visions of the smart home [64], and also evident in our findings. Inspirations towards this end could be to speculate [9] or provoke households [50] though design to consider if these expectations are also meaningful and aligned with desires of sustainable energy consumption. A few HCI studies have already looked for possible ways to challenge expectations of comfort through smart technology. Clear et al. study of drifting [13] points to different opportunities to design smart thermostat by exploring alternative means embedded in heating practices to pursue comfort, while Pink et al.'s [47] design intervention 'Acclimatiser' automatically lowers the temperature by one degree over an extended period in effort to establish a new 'norm' of thermal comfort over time.

While these studies seem promising we also suggest that considerations are put into reimaging how to design pleasurable and aesthetic pleasing experiences within the smart home that promote lower energy consumption. As desires are reproduced through social practices [58], it is experiences, moods and meanings that shape how people use designs within the home, thus we see this as a promising way towards designing the sustainable smart home. Aspirations towards this end could be to explore an alternative take on the hedonist. While the hedonist embodies connotations of a pleasure-seeker where the pursuit for happiness, through consumption, is the most important thing in life, alternative hedonism, as suggested by Soper [61], recasts the hedonist as an anti-consumerist that challenges conceptions of aesthetically-pleasing life.

Hallnäs and Redström's concept of downtime or slow time [22] could open further opportunities to reimaging the hedonist in the design of the smart home as the 'desired thing'. The slow time concept aligns well with Pierce et al.'s [44] idea of 'slow energy' that encourage more thoughtful energy consumption embedded into everyday practices. Wessman and colleagues [32,67], for example, explores the concept of slow energy as 'peacetime' through design. Their design invites households to partake in 'inspiring alternative activities' without requiring any electricity. We see this as a promising end towards households' pursuit of creating less energy intensive, but still desirable, meaningful and pleasurable moments within the smart home.

CONCLUSION

In this paper, we have analysed the different desires embedded in smart home technologies as interpreted by 23 participating households. Drawing on Nelson and Stolterman's concept of desiderata we developed a typology of different desires for the smart home. We structured these as three smart home personas: the helper, optimiser and hedonist, which align with desiderata's three approaches to desire (reason, ethics and aesthetics).

What our findings show is that different desires embedded in the smart home also shape household expectations and practices to impact energy consumption in different ways. Most interestingly, these desires both compliment and contrast each other, highlighting an energy paradox in the desirable smart home. While smart home technologies afford households aesthetically pleasing experiences that reflect a modern lifestyle, they can also undermine the desire to live sustainability.

Based on these findings, we conclude that if designers of smart home technology seek to aspire towards sustainable change, we need to approach the desirable smart home more holistically through concepts like desiderata. Towards this agenda, we suggest that HCI practitioners and researchers engage with aspirations to both challenge and enhance desirable everyday experiences that also promote more sustainable energy use.

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